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Priorities in the Management of the Open Abdomen

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Abstract: ***The open abdomen is a crucial tool in damage control surgery that mainly aims to control sepsis, facilitate the next surgical approach and prevent compartment syndrome. In its implementation, it is necessary to opt for the temporary closure method that provides the greatest advantages for the specific clinical context and to ensure close monitoring to ensure conditions that promote definitive fascial closure, which ideally should occur in the shortest possible time, to prevent the occurrence of potentially fatal complications.***

Keywords: open abdomen, sepsis, nutrition, damage control, temporary closure, abdominal compartment syndrome, enteric fistula, fascial closure, negative pressure

1. Introduction

A crucial aspect of damage control surgery is the application of methods that involve leaving the abdomen open. The open abdomen is an important tool in the arsenal of emergency surgery, both in pathologies associated with trauma and in those that are not. ' in the open abdomen the aponeurosis deliberately remains open, while the visceroperitoneal contents are protected by other methods. Since the first description of the open abdomen, attributed to Andrew 1. McCosh in 1897, multiple temporary closure techniques have been described, each with better results than the last. ' in the past these techniques were associated with infectious and hemorrhagic complications that mostly determined clinical deterioration to fatality and it was not until the 1990s that the understanding of trauma physiology allowed advances in critical care medicine that laid the foundation for damage control surgery and vindicated the abbreviated laparotomy as a crucial step in the fight against the lethal triad of hypothermia, coagulopathy and acidosis. [3, 4]

Indications for open abdomen
Although exposure of peritoneal contents implies significant fluid, electrolyte, and protein losses, aponeurotic retraction and risk of developing enteric fistulas, the use of the open abdomen as part of damage control surgery strategies is justified in the therapeutic algorithm of potentially fatal conditions due to its indisputable benefits. Its application is mainly aimed at:

Control of sepsis and hemorrhage in a patient whose unitable conditions do not allow a definitive surgical resolution in the first intervention, meriting a planned re - exploration (second look) and reducing the duration of this first surgical time.

To facilitate the following surgical approach.

Prevention of abdominal compartment syndrome (often conditioned by significant visceral edema resulting from resuscitation and massive transfusion in the context of hemorrhagic shock or the use of hemorrhagic packing techniques). [1]

Thus, abdominal fascial closure should be considered when the risk of abdominal compartment syndrome is limited, the source of sepsis is controlled and no further laparotomy procedures are planned.

Ultimately, the fundamental objective is to achieve definitive closure of the abdominal cavity in the shortest possible time and with the least number of complications, the most feared being the production of a hostile abdomen, a clinical condition in which the exposed contents of the abdominal cavity are fragile and scarred into a single solid mass, with retracted and fibrous borders, often associated with enteric fistulas, situations that make dissection and closure difficult, considerably increasing morbimortality. [5, 6]

This is achieved by prioritizing two categories of interventions:

- Those that achieve control of the infectious source and mitigate the systemic effects of sepsis and,
- Those that create favorable local and systemic conditions conducive to healing.5

These interventions result in a series of decisions that the surgeon makes from the moment he opts for deferred abdominal closure and that determine the conditions and the time in which the definitive closure is achieved.

Appropriate temporary closure
The recovery of the integrity of the abdominal wall is the ultimate goal of open abdominal management, however, this is not always possible, making it necessary to resort to temporary closure techniques.
Without adequate temporary closure, complications such as enteric fistulas or incisional hernia are high.
When a temporary closure is chosen, it is pursued:

- Avoid evisceration
- Facilitate rescanning
- Avoid intra - abdominal hypertension and compartment syndrome.
- Facilitate eventual primary fascial closure.7

The role of the temporary closure is crucial and the choice of the latter determines the risk of complications to which it will

predispose since no technique is free of them. The ideal temporary closure technique is one that:

- It acts as a barrier, isolating the contents of the abdomen from the environment.
- Allows the collection of abdominal fluids
- Quick to install and remove, it allows easy access to the peritoneal cavity at a later date.
- Prevents fascial retraction and protects the fascia for eventual definitive closure it is profitable
- It allows the nursing staff to carry out maneuvers.

Although multiple techniques have been used for temporary abdominal closure, negative pressure therapy is currently considered the best option in the setting of sepsis of intra - abdominal origin. Despite its high cost, its use provides additional advantages in the septic open abdomen in terms of elimination of proinflammatory cytokines, decrease and estimation of leakage, as well as migration of immune cells and acceleration of granulation tissue formation, while allowing its association with fascial traction techniques that prevent retraction and promote subsequent closure, in addition, decreased intra - abdominal pressure measurements have been reported with the use of negative pressure therapy when confronted with other techniques, which prevents the development of abdominal compartment syndrome. This effect is presumed to be from aspiration of ascites fluid, so these findings should be interpreted with caution in the care of suspected retroperitoneal pathology. Furthermore, despite the concern, there is no evidence to support the existence of an increased risk of enteric fistulas associated with its use.[3, 7, 8, 12, 13]

Other temporary closure techniques such as skin closure may provide interesting benefits for patients outside the context of sepsis. Thus, trauma management may find convenient the high availability of the necessary materials in skin closure, available in virtually all centers and whose rapid placement and subsequent removal may be useful in a patient with hemodynamic instability, while in cases of intestinal ischemia may benefit from a method that allows visualization of intra - abdominal contents, such as the Bogota Bag, so the surgeon's choice of the technique to use must take into account the particularities of the clinical scenario he is facing and the particularities of the care center.[14]

Comparison of common open abdomen techniques

Technique	Advantages	Disadvantages
Leather closure	Cheap, fast (can be carried out in approximately 60 seconds), always available, does not require special equipment, minimizes heat and fluid loss, reduces contact with the outside and the risk of developing enterocutaneous fistulas	It damages the skin, does not allow quantifying fluid loss, does not prevent the development of compartment syndrome, has a risk of evisceration, does not prevent fascial retraction.
Bogota Stock Exchange	Cheap, high availability, allows visualization of the interior of the cavity in case of suspected necrosis or ischemia, reduces the loss of heat and fluids and allows the quantification of the latter.	Damage to the fascial edges, risk of evisceration, does not prevent fascial retraction, does not allow quantifying fluid loss.
Barker Vacuum Pack	Inexpensive, highly available, minimizes heat and fluid loss allowing the quantification of the latter, avoids damage to the skin edges by not requiring sutures, allows its association with fascial traction techniques that favor posterior closure	Risk of evisceration in case of adhesive film peeling, offers minimal control over liquid losses, requires availability of a wall suction system
Vacuum - assisted shut - off systems	It does not cause fascial or skin damage, maintains a constant tension that decreases aponeurotic retraction and progressively decreases the length of the defect, promotes an increase in blood perfusion and migration of fibroblasts that contribute to healing, decreases the risk of compartment syndrome; it favors the reduction of bacterial load, edema and proinflammatory cytokines, allows its association with fascial traction techniques that favor posterior closure	Requires the use of expensive specialized equipment, is not available in all centers, often needs to be placed under general anesthesia

Limiting losses

An important aspect of the management of the open abdomen is the reduction of losses. Keeping the abdomen open, depending on the technique used, promotes protein, electrolyte and fluid losses in the various anatomical compartments to a greater or lesser extent.

Major tissue losses resulting from trauma or surgical debridement increase insensible fluid losses making estimation challenging: additionally, conditions such as fever can increase fluid losses, while open wounds allow sustained evaporation, making it necessary to constantly monitor hydration status. This is of vital importance, especially in patients with fistulas or high - output stomas. Clinical signs of hypovolemia may not appear until losses are really significant, so markers of SIRS and sepsis are preferred instead. Fluid monitoring should focus special attention on hourly urine output, which is an early marker of the predominance of losses over inflows, is simple to measure, inexpensive, and can be performed quickly in most patients, Invasive monitoring, such as central venous pressure measurement, is a prudent measure in patients with associated renal failure.[6, 8]

Inadequate volume replacement coupled with hypotonic fluid loss through the wound and exposed peritoneal cavity can lead to hypervolemic hypernatremia; in addition, due to the large volume of exudate compared to that caused by other wounds, greater daily losses of potassium, phosphorus, magnesium, and calcium occur in the open abdomen, so serum electrolyte levels should be monitored relatively frequently.[8, 9]

In the case of fistulas, the leakage must be carefully estimated in order to be replaced with the appropriate solution. The selection of this replacement solution is based on the tonicity of the leakage, depending on the fluid in question. Upper tract fistulas (up to the stomach) are hypotonic and should be

replaced with hypotonic solutions. Mid - tract fistulas (duodenum, bile duct, pancreas, and small intestine) are isotonic and should be replaced with isotonic solutions. Distal fistulas (colon and rectum) are again hypotonic.[8]

Proteins play a critical role throughout the wound - healing process. Cells of the immune system are predominantly composed of proteins and are indispensable for initiating an effective inflammatory response during tissue repair. Adequate protein supply is crucial to ensure continuous and effective healing. Since collagen is the predominant protein synthesized in the healing wound, a protein deficiency can compromise collagen synthesis and fibroblast production, thus slowing the healing process.[9]

Protein loss secondary to the open abdomen is significantly greater than that caused by other soft tissue wounds. This difference is further enhanced by the large volume of exudate from these wounds coupled with the insensible losses present in any large wound. in recent years it has been suggested that quantification of exudate using negative pressure systems is useful for estimating protein losses with an estimated rate of 2.9 g/dL per volume of exudate obtained. Constant monitoring may allow adequate replenishment through nutrition, avoiding underestimation of losses and underfeeding.[8, 10, 11]

Sepsis control

Multiple organ dysfunction is the final and often lethal stage of septic and hemorrhagic shock. The mechanism by which it develops is dependent on excessive systemic inflammation that alters multiple complex molecular signaling pathways leading to alterations in cellular metabolism, injury and apoptosis. In the pathophysiology of sepsis, alterations in microvascular perfusion, coagulopathy, and increased capillary permeability have been demonstrated, which produce organ dysfunction at the respiratory, cardiovascular, hepatic, renal, gastrointestinal, immunological and endocrine levels.[12]

Although sepsis secondary to intra - abdominal injury results in systemic inflammation, evidence points to this response being amplified in the peritoneum. Microcirculatory dysfunction is secondary to shock (septic or hemorrhagic) resulting in loss of intestinal barrier function, intestinal edema, and production of ascites fluid with elevated levels of proinflammatory mediators. Inflammatory ascites perpetuate systemic inflammation, which can degenerate into multiorgan failure.[12, 13]

Significant differences have been reported between cytokine levels in the peritoneum of animal models of intra - abdominal sepsis between those specimens that survive and those that die, and it has been observed that the use of negative pressure therapy is associated with a significant reduction in organ damage and mortality associated with sepsis. The proposed mechanism is that the constant drainage of inflammatory mediators, both peritoneally in the ascites fluid and in the plasma, promotes the regulation of the systemic inflammatory response, resulting in a significant decrease in histological damage to the lungs, intestine, kidneys and liver, and associated mortality.[14, 15, 16]

The first priority in the management of the septic open abdomen is to control the septic source and mitigate the systemic effects of sepsis. This is achieved by repairing or bypassing the intestinal contents, often through drains or systems that allow external drainage of secretions and gas, thus decreasing the bacterial load and relieving pressure on the affected intestinal segment, preventing further complications. Sepsis itself is a potential cause of compartment syndrome that ultimately compromises splanchnic perfusion, Antibiotics should be initiated early to avoid progression to shack and multiple organ failure, as well as the physiological alterations that determine the persistence of systemic.[5, 14, 17]

In the particular context of intra - abdominal sepsis, keeping the abdomen open is an alternative that seeks to avoid the formation of additional septic foci and protect the abdominal wall for eventual closure. The lack of systematization in its management can, however, condition the appearance of a hostile abdomen, which frequently presents with intestinal perforations, which are usually managed with primary closure and splinting with probes with variable results. In recent years, intestinal content diversion techniques have been described, such as the Rivera condom and floating stoma techniques, which seek to control the septic focus by preventing leakage of stomas and enterocutaneous fistulas into the abdominal cavity, thus reducing peritoneal imitation and, consequently, the systemic inflammatory response.3, [5, 18]

Ultimately, it should not be lost sight of the fact that, together with adequate hemodynamic and ventilatory support, the management of abdominal sepsis is primarily surgical and is based primarily on control of the septic source, by removal, diversion and drainage of toxic products.[18]

Optimizing nutrition

The first step in nutritional support is the assessment of baseline status. Estimation of requirements can be performed using one of the many equations designed for critically ill patients: Penn State, Faisy, Brandi, Swinamer or Ireton - Jones. Above all, given that sarcopenia has been associated with increased morbidity and mortality, a key objective in the management of these patients is to achieve the antagonistic anabolic response described by Wolfe, which achieves the suppression of protein catabolism and which only occurs in circumstances of surplus of this macronutrient. In general, most patients with open abdomen, and especially those who develop enteroatmospheric fistulas (particularly high output) will require 25 to 35 kcal/kg/day non - protein and 1.5 to 2.5 g protein/kg/day. Clinically, the most reliable indicator of adequate nutritional support is timely wound granulation.8, [24, 26, 29]

As critically ill patients who will often require prolonged hospital care, progression to persistent inflammation, immunosuppression and catabolism syndrome (PICS) is not uncommon in the open abdomen setting. While sepsis control provides benefits associated with decreased inflammation and improved immune response, the state of hypercatabolism is improved primarily by optimizing nutritional inputs of protein, amino acids (arginine, leucine, isoleucine, valine and glutamine, mainly), and omega - 3 grade acids by promoting anabolic response, minimizing lean tissue loss, inhibiting

oxidative injury, reversing cellular immunosuppression and modulating the synthesis of proinflammatory agents. In this regard, supplementation of 2 g/day of EPA and DHA has been shown to be effective when these effects are intended.2[5, 26, 28]

Although well - nourished patients can tolerate a period of 7 to 10 days without any nutritional support (which can be considered in patients in whom early fascial closure is anticipated), it has been shown that the hypermetabolic response observed in critically ill patients is attenuated by early initiation of enteral nutrition. Early nutritional support, initiated within the first 24 - 48 hours after admission to the Intensive Care Unit (ICU) improves healing, reduces hospital and ICU stay, decreases catabolic and injury response, preserves the integrity and function of the gastrointestinal tract, decreases infection rates and improves survival after critical illness. This translates into a reduction in complications and costs of care. In addition, lower rates of septic complications (pneumonia, bacteremia, and intra - abdominal abscess) have been reported in patients whose nutritional support is provided by enteral route with respect to those who receive this supply parenterally. Thus, it is preferable that parenteral nutrition be considered as an option when energy or protein requirements cannot be met through the enteral route.[8, 19, 20, 27]

Enteral nutrition should be preferred whenever feasible, although in most patients treated with open abdominal techniques this is not possible due to the initial pathological lesion. In them, rather than reintroducing the enteral route, while providing parenteral support, priority should be given to achieving:

- infection control
- Reversal of the shock
- Injury repair in planned interventions[8]

It is a priority that enteral nutrition be provided as soon as possible, even in patients with enteroatmospheric fistulas. The risks of prolonging the initiation of the enteral line include: atrophy of the mucosal barrier, increased bacterial translocation, and increased risk of infectious complications, which together exacerbate intestinal edema and may delay fascial closure. Although the fear that initiating enteral nutrition may increase the risk of anastomotic leakage or cause fistula formation, contrary to what would be expected, it has been shown that enteral nutrition increases splanchnic perfusion, which may reduce intestinal edema with the logical consequence of facilitating the definitive closure that this effect entails. Likewise, the results observed in studies comparing early initiation of enteral nutrition in patients with gastrointestinal anastomosis show a significant reduction in the incidence of complications without an increase in the incidence of dehiscence. Although these studies have been carried out outside the context of the open abdomen and should be interpreted with caution, given their magnitude, the results suggest that it is reasonable to transfer them to this setting, since the potential benefits outweigh the risks in both pediatric and adult populations.2[0, 21, 22, 23, 24]

Procuring early closing

The ultimate goal of open abdominal techniques is to achieve eventual closure in the shortest possible time, avoiding whenever possible the appearance of additional complications. As previously mentioned, fascial closure should be considered when the risk of abdominal compartment syndrome has been overcome, the source of sepsis is controlled and no further laparotomy procedures are anticipated.

Thus, in the open abdomen, two moments are recognized for definitive closure:

- Early closure, occurring in the first 4 - 7 days after the first surgical intervention,
- Late closure, which occurs a day or more after the index procedure[1]

Since the Introduction of open abdominal techniques, many studies have associated increased morbidity and mortality with delayed abdominal wall closure. The risks of delaying fascial closure include aponeurotic retraction with the consequent modification of the anatomy and loss of domicile, in which cases planned hernia management may be chosen, In addition, prolonged visceral exposure may lead to a higher risk of developing enteric fistulas, further prolonging definitive fascial closure, while, contrary to traditional belief, a lower incidence of incisional hernia is observed in patients in whom early closure is achieved.7[, 30, 31]

Thus, whenever possible, early fascial closure should be sought, controlling, not only at admission but throughout open abdomen therapy, hydric resuscitation, inflammation, local and systemic, and sepsis, all conditions that can hinder it. The ideal moment for this definitive closure is when the patient is stable, in good nutritional condition and the distance between both fascial edges does not exceed 7 centimeters.7

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